ATMOSPHERIC CORROSION RATES NEAR TYPICAL FOREST INDUSTRIES OF B.C.

Province of British Columbia
Ministry of Environment

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ATMOSPHERIC CORROSION RATES NEAR TYPICAL FOREST INDUSTRIES OF BRITISH COLUMBIA

by

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INTRODUCTION

Atmospheric corrosion rate has been considered to be an important parameter for the assessment of the effects of industrial pollution on various metals. In a few instances this parameter may be potentially used as a relative indicator of the assimilative capacity of a particular region provided suitable standards are established. Corrosion rates in the interior and coastal areas of B.C. involving two different forest products industries have been studied by the British Columbia Ministry of Environment. The first study involves assessment of corrosion impacts in the vicinity of a Kraft pulp mill in the Castlegar area in southeastern British Columbia. The second case is an assessment of corrosion impacts in the vicinity of a woodwaste power boiler located in the coastal area of Victoria. Figures 1 and 2 show the locations of the two studies. For the pulp mill in Castlegar, the short-term as well as the long-term corrosion rates of different metals were investigated. The results have been compared with the corrosion rates at a background site located in Nelson and also with those near the smelter in Trail located about 16 km south of Castlegar. For the woodwaste boiler in Victoria the corrosion rates were monitored downwind of the mill and compared with those in a coastal background location. In the Castlegar area corrosion rates of duralumin alloy, aluminum, copper, zinc and mild steel were examined. In the Victoria area atmospheric corrosion of mild steel was investigated. Relevant ambient air quality parameters were also monitored in both the locations. These parameters included total suspended particulate matter, sulphation rate and soiling index.

EMISSION CHARACTERISTICS

In the Castlegar area the pulp mill is the major source of air pollution. The Kraft mill has a design production capacity of 600 t/d(tons/day) of bleached pulp. Table 1 shows the summary of emissions from the major sources in the pulp mill. The emission consists of approximately 2 500 kg/day of fly ash, 1000 kg/d of sodium salt aerosols and 2 500 kg S/day as

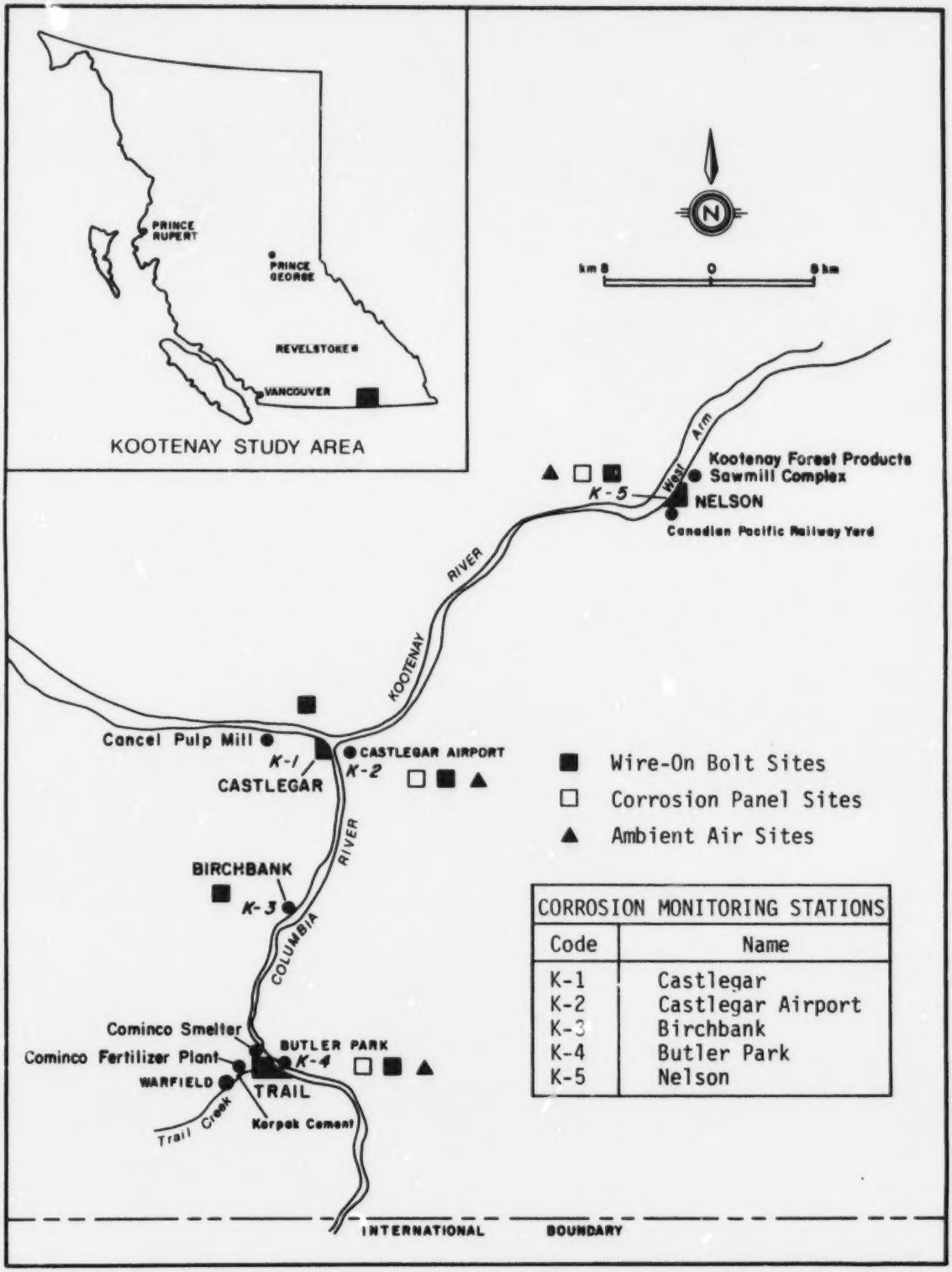

Figure 1 Location of Major Emission Sources and Corrosion Monitoring Sites in Kootenay Area

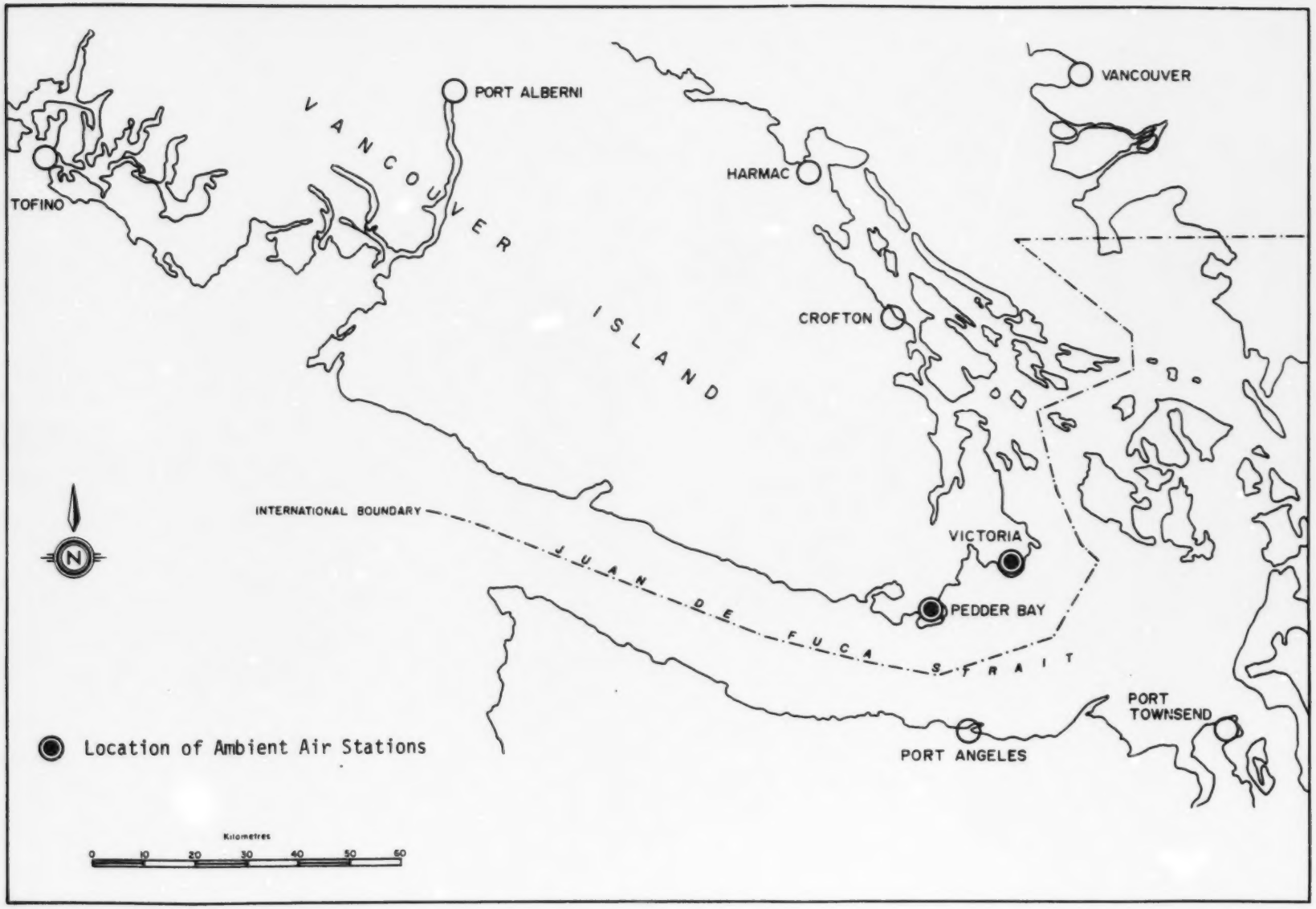

Figure 2 Location of Ambient Air Stations in Victoria Area

combined sulphur dioxide and total reduced sulphur compounds, primarily hydrogen sulphide. The recovery boiler is the main source of the reduced sulphur compounds. These are gaseous contaminants with hydrogen sulphide being the chief constituent. A small amount of sulphur dioxide also emanates from the recovery boiler. The particulate matter in the form of sodium salts such as sulphate and carbonate is discharged from the recovery boiler. The particulate matter in the form of fly ash is emitted from the power boilers which use hog fuel as the primary fuel.

The woodwaste power boiler in Victoria has a total design capacity of 81 720 kg/hr of steam. The total emission consists of approximately 7 000 kg/day of particulate matter. Sodium chloride (common salt) represents 60% of the total particulate matter emitted. Approximately 80% of the emitted salt particles have a submicron particle size which is less than 1 μm.

AMBIENT AIR QUALITY

Generally atmospheric corrosion rate has a close correlation with the ambient air quality in a particular area. Increased corrosion rate is normally a reflection of degraded ambient air quality which is dependent on the assimilative capacity of the region.

In reality the atmospheric corrosion represents the total effect of a combination of various factors such as temperature, relative humidity, and concentrations of different types of contaminants in the ambient air. In the case of the pulp mill in Castlegar sulphur compounds have been observed to be the primary factor affecting the corrosion rates. The measurement of sulphation rate represents the concentration of gaseous sulphur compounds in the atmosphere. Sulphation rate, total suspended particulate (TSP) matter and its sulphate content were monitored at three locations, namely, Nelson, Castlegar and Trail. The station at Nelson having the least industrial influence has been treated as the background site. Table 2 indicates typical levels of total suspended particulate matter and sulphation rate in the Castlegar study area. In Castlegar as well as Trail the sulphation rate

is approximately six times that of Nelson. In Trail the high sulphation rate is caused by the emission of sulphur dioxide from the non-ferrous smelter. Although the level of the total suspended particulate matter is higher in Nelson, the sulphate content in TSP is considerably lower than that found in Castlegar and Trail. The sulphur compounds emitted from the pulp mill and the smelter in these two areas account for the relatively high sulphate content.

For the study in Victoria, emphasis was placed in monitoring the fate and effects of fine salt particles emitted by the woodwaste power boilers. These boilers like any other coastal operations use wood which has been transported over the sea. The salt absorbed during marine transportation is emitted during the process of combustion. Table 3 indicates the ambient air parameters monitored and their average values. The results for the two sites are shown. The site at Suburban Motors represents the point of maximum impingement downwind from the boilers. Pedder Bay is a coastal background site. At the Suburban site the concentrations are given for both the operating and the shut-down periods. There is indication that approximately 18% of the total suspended particulate matter is contributed by the boiler and about 63% of the atmospheric salt originates from the mill. Most of the salt in the area influenced by the mill is extremely fine and has a mean particle size of 0.5 μm. At the coastal background site the salt particles are considerably larger with a mean particle diameter of 4.5 μm. Figure 3 shows the average size distribution of sodium chloride in suspended particulate matter in the Victoria area. Although the total dustfall is low, the contribution by the mill amounts to approximately 36%. The salt in the dustfall contributed by the mill amounts to about 61%. As expected in the absence of any major source of sulphur compounds the sulphation rate is relatively low. In this case the concentration of fine anthropogenic sodium chloride particles has been considered to be the primary factor for having enhanced corrosion impact in Victoria relative to the coastal background area of Pedder Bay.

TABLE 1
EMISSION CHARACTERISTICS

A. Castlegar Pulp Mill

Type	Rate kg/d	Source
Fly ash	2 500	Power Boilers
Sodium aerosols	1 000	Recovery Boiler
Total S compounds	2 500	Recovery Boiler
Total	6 000	

B. Victoria Woodwaste Power Boiler

Type	Rate kg/d	Source
Fly ash	2 800	Power Boilers
Sodium chloride	4 200	Power Boilers
Total	7 000	

TABLE 2
TYPICAL AMBIENT AIR QUALITY IN CASTLEGAR STUDY AREA

Location	Sulphation Rate mg $SO_3/dm^2.d$	TSP* g/m^3	% Sulphate in TSP
Nelson	0.17	107	4
Castlegar	1.05	85	12
Trail	1.07	70	17

* TSP - Total suspended particulate.

TABLE 3
AMBIENT AIR QUALITY IN VICTORIA STUDY AREA

Parameter	Suburban[1]		Pedder Bay[2]
	Operations	Shut-down	
TSP[3], g/m^3	65	53	17
TSP Salt (NaCl), g/m^3	4	1.5	1.9
TSP Salt Size (Dp_{50}), µm	0.5	-	4.5
Soiling Index, COH	0.16	-	0.05
Sulphation Rate, mg $SO_3/dm^2.d$	0.21	0.24	0.10
Dustfail, $t/mi^2.m$	11	7	4
Dustfall Salt, $t/mi^2.m$	1.8	0.7	0.6
Annual Relative Humidity, %	75	-	77

1 Mill influenced site during operating and shut-down periods.
2 Marine background site.
3 Total suspended particulate matter.

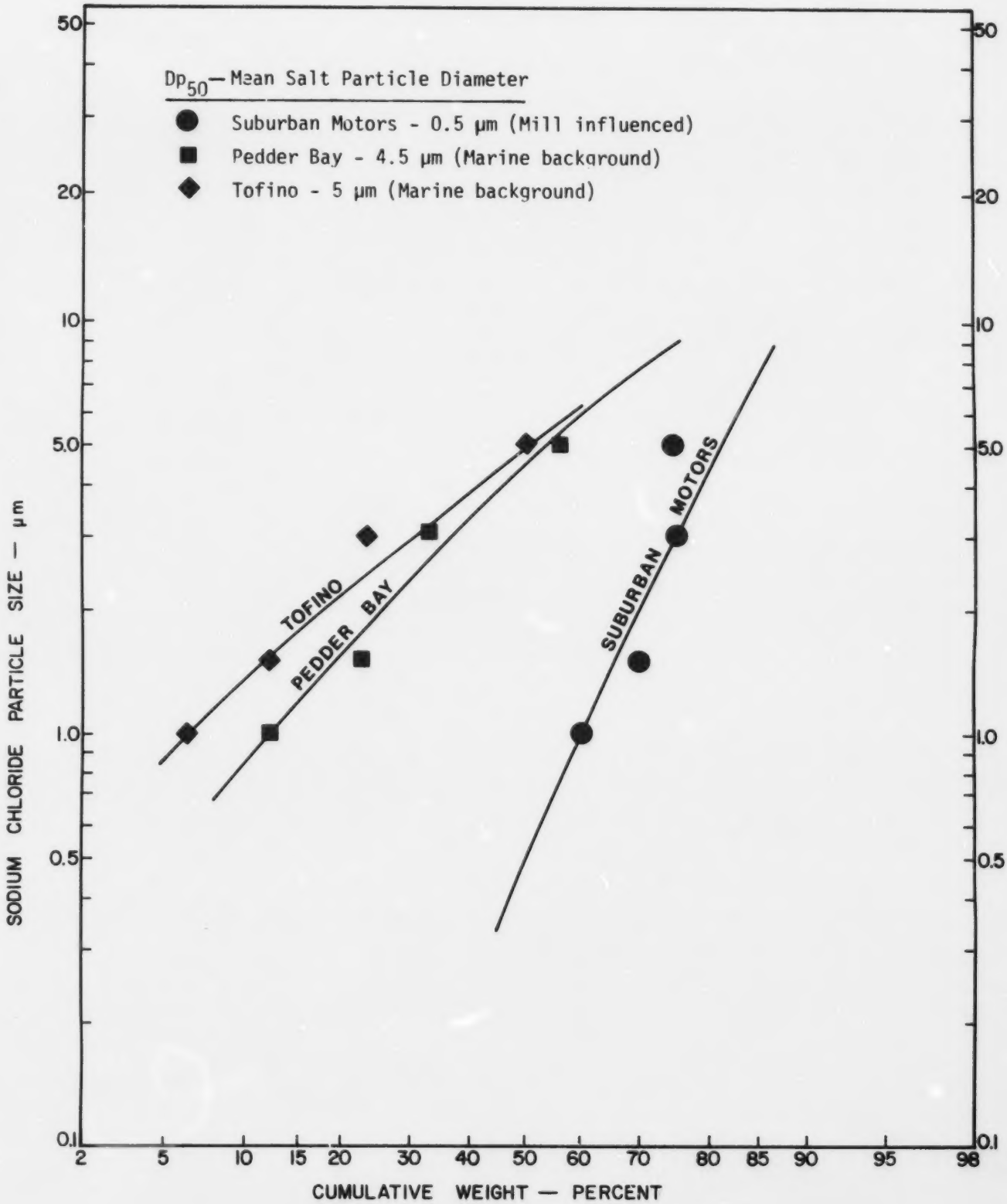

Figure 3 Average Size Distribution of Sodium Chloride in Suspended Particulate Matter in Victoria Area

ATMOSPHERIC CORROSION RATES

Castlegar Area

Two separate tests were conducted in this study area to monitor the atmospheric corrosion rates. The first test involved short-term exposure periods using wire-on-bolt test samples. The second one involved the conventional long-term exposure using six different metal panels. Figure 1 shows the locations of the test sites. There were three sites for the long-term corrosion test and five sites for the short-term test. As indicated earlier, ambient air quality was also monitored at these sites. The site at Nelson has been treated as the background site.

For the short-term test a unit consisting of Al-plastic and Al-Cu couple was used at each site for three months. The weight loss of aluminum in the Al-plastic couple indicates general corrosion. The loss of metal in the Al-Cu couple is a measure of the galvanic corrosion of aluminum. Table 4 shows the results of the short-term corrosion test and the average sulphation rate at the five different locations. The corrosion loss of aluminum was considerably lower for the Al-plastic couple compared to that of the bimetallic Al-Cu couple. This indicated that the loss due to galvanic corrosion was several magnitudes higher than the general corrosion of aluminum alone. There is a linear relationship between the general corrosion loss of aluminum and the sulphation rate as indicated in Figure 4. The pulp mill area in Castlegar has approximately three to four times the corrosion rate of the background location in Nelson. The maximum sulphation rate has been found at the Castlegar airport, the average value being six times that of the background in Nelson. Figure 5 shows the seasonal pattern of corrosion loss based on Al-Cu tests. The maximum corrosion impact seems to occur in the spring with relatively lower impacts in the summer, fall and winter season.

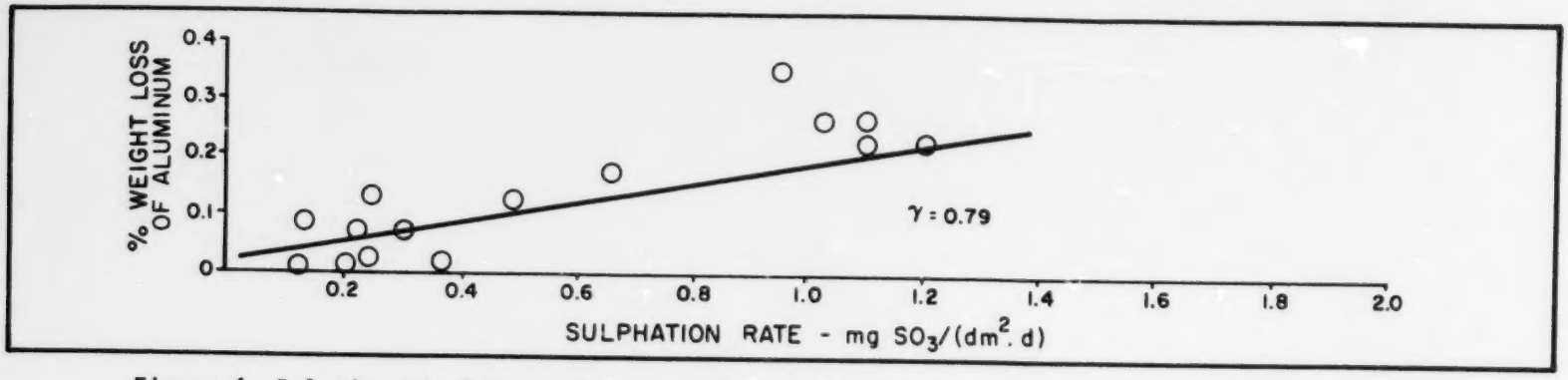

Figure 4 Relationship Between Corrosion Loss and Sulphation Rate Based on Al-Plastic Tests

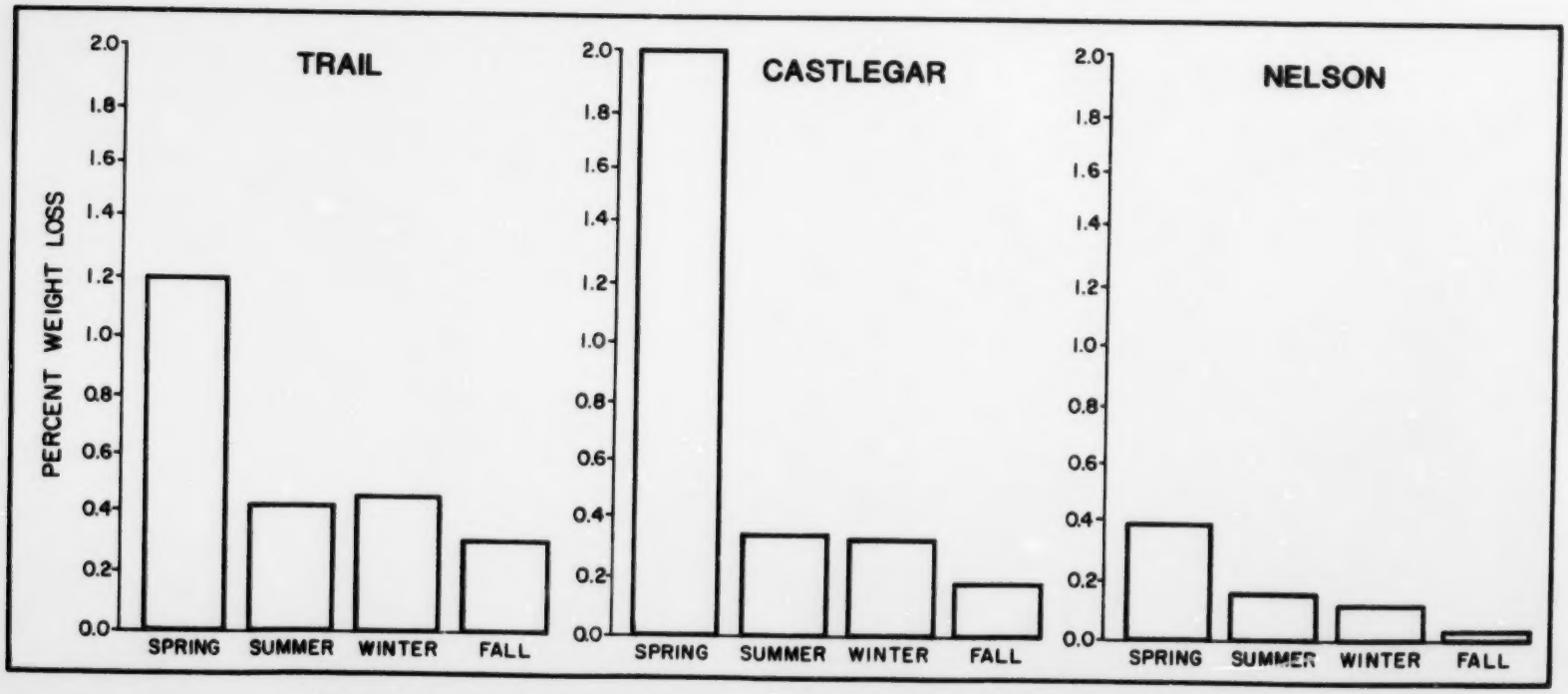

Figure 5 Seasonal Pattern of Corrosion Loss Based On Al-Cu Tests

TABLE 4

CORROSION FOR 90-DAY EXPOSURE BY WIRE-ON-BOLT METHOD

Station	Type of Emission Source	% Wt. Loss of Al Al-plastic Couple	% Wt. Loss of Al Al-Cu Couple	Average Sulphation Rate mg $SO_3/dm^2.d$
Nelson K-5	Urban-Rural Site	0.03	0.23	0.19
Castlegar K-1	Pulp Mill	0.087	0.67	0.31
Castlegar Airport K-2	Pulp Mill	0.197	0.89	1.20
Birchbank K-3	Smelter	0.15	0.34	0.67
Butler Park K-4	Smelter	0.22	0.70	1.13

In the Castlegar area the long-term test involved exposure of seven different metal panels with dimensions of 15 cm x 10 cm x 0.13 cm. The metal specimens used in this test included copper, zinc, aluminum-clad, aluminum-unclad, galvanized steel and mild steel. Cladding consists of exterior coating of high purity aluminum on duralumin alloy, usually 2 1/2% of the thickness of plate per side. The exposure period for all specimens extended from six to twenty-four months. Duplicate specimens were removed at an interval of six months. Corrosion loss was determined by the loss in weight for each specimen. Table 5 shows the corrosion rates for different metals at the three sites located in Nelson, Castlegar, and Trail. The corresponding sulphation rates are also indicated in Table 5. All metals studied near the pulp mill and the smelter have considerably higher rates of corrosion than the corrosion rate at the background station in Nelson.

In the vicinity of the pulp mill in Castlegar, copper has a higher corrosion rate than that found near the smelter in Trail. Also in the initial period the unclad aluminum has a higher corrosion rate near the pulp mill than that found near the smelter. All other specimens have higher corrosion rates near the smelter compared to the corrosion rates near the pulp mill. It is interesting to note that there is virtually no difference in the corrosion rates between the clad and the unclad aluminum near the pulp mill and the background location in Nelson. Although in the vicinity of the smelter the clad aluminum has a higher corrosion rate than that found for the unclad specimen. This is graphically shown in Figure 6. The difference may be most likely due to the difference of sulphur compounds and their reactivities with the specific metals. In the Castlegar area copper and the unclad aluminum specimens are possibly more reactive to hydrogen sulphide from the pulp mill than to sulphur dioxide emitted by the smelting operation in Trail. At all three locations mild steel indicated the highest corrosion rate and the aluminum has the lowest corrosion rate. Based on the mild steel specimens, the pulp mill area in Castlegar has approximately twice as much relative corrosivity compared to the background. For the same metal the Trail area has about three times as much corrosivity relative to the background in Nelson.

TABLE 5

CORROSION RATES AT WEST KOOTENAY SITES

Location	Exposure Period Months	Corrosion Rate µm/year Copper	Zinc	Al-clad	Al-Unclad	Galvanized Steel	Mild Steel	Sulphation Rate mg $SO_3/dm^2.d$
Nelson (K-5) Background Site	6	0.475	0.60	0.073	0.073	0.50	19.35	0.18
	12	0.45	0.50	0.070	0.070	0.45	17.18	0.13
	18	0.50	0.43	0.073	0.073	0.38	15.98	0.12
	24	0.45	0.43	0.073	0.073	0.35	16.65	0.10
Castlegar (K-2) Pulp Mill Site	6	1.88	1.98	0.36	0.39	2.1	59.30	1.00
	12	2.23	1.68	0.35	0.40	1.8	52.68	0.85
	18	2.68	1.70	0.33	0.35	1.8	45.83	0.85
	24	2.58	1.48	0.25	0.25	1.56	35.42	0.81
Trail (K-4) Smelter Site	6	1.48	2.03	0.43	0.35	2.40	88.98	1.01
	12	1.60	1.78	0.40	0.28	2.20	70.55	1.05
	18	2.13	1.78	0.43	0.28	2.08	53.18	0.99
	24	2.03	1.80	0.33	0.28	2.03	47.55	1.11

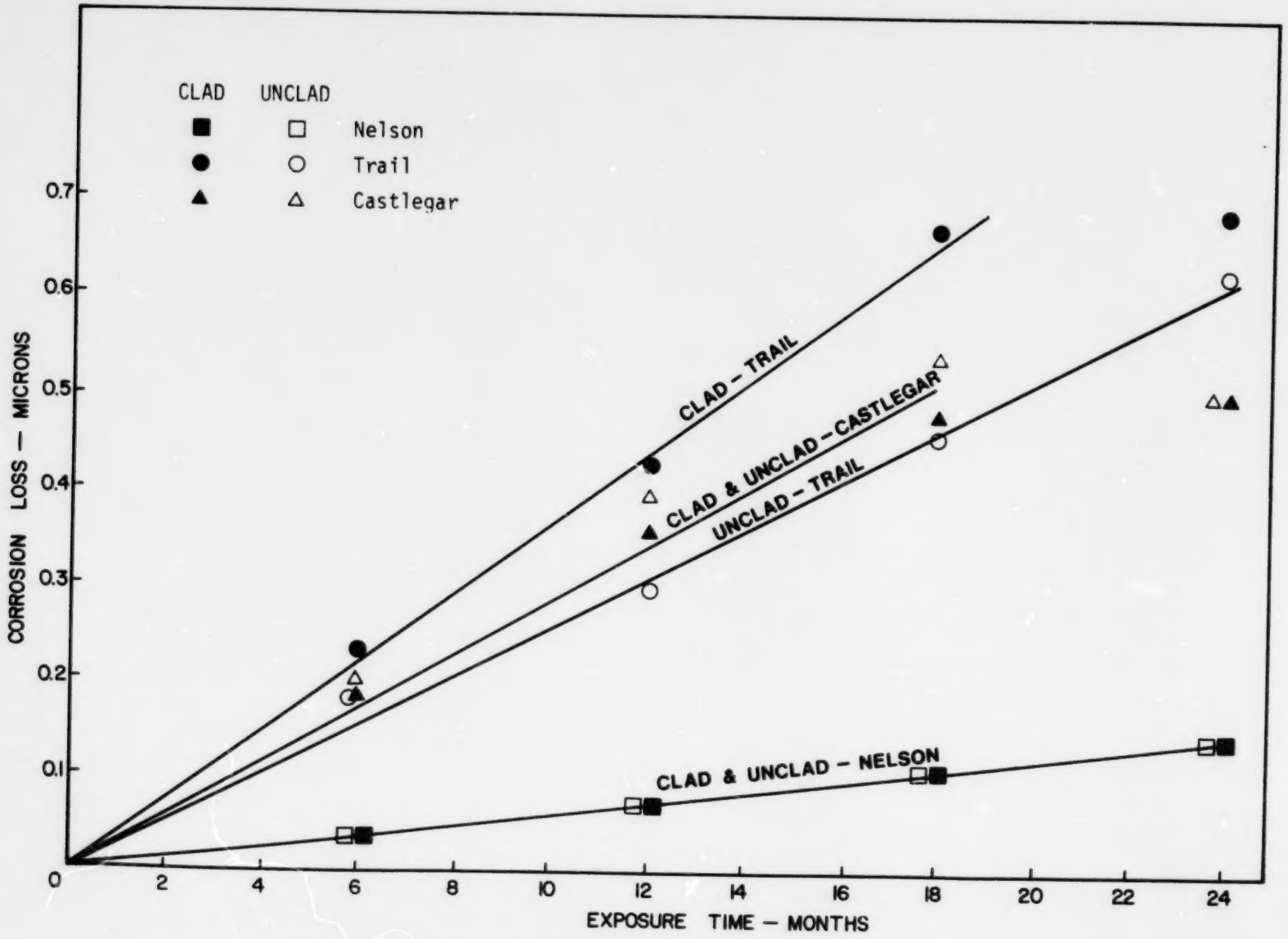

Figure 6 Corrosion Loss for Clad and Unclad Aluminum

Victoria Area

For the study conducted in the Victoria area the atmospheric corrosion losses were determined by the rack exposure of 30 cm x 15 cm mild steel coupons at two locations as shown in Figure 2. As stated earlier the station at the Suburban Motors represents a downwind area generally affected by the mill emissions. The station at Pedder Bay represent the coastal background location which is not affected by salt sprays. Table 6 shows the average corrosion rates at these two locations over the exposure period of about twenty-one months. The relative corrosivity between the two stations is also shown in Table 6. The data indicated that the average corrosion rate in the downwind area of the mill was considerably higher than that in the coastal background area. In the mill-influenced area the rate steadily decreased from 36.5 μm/yr to 27.5 μm/yr over a period of twenty-one months. In the coastal background the rate decreased from 21 μm/yr to 15 μm/yr over the same period of time. Figure 7 shows the average corrosion rates for the two stations. The relative corrosivity, based on the metal loss due to corrosion, is significantly higher at the Suburban station than that at Pedder Bay. The relative corrosivity at the initial stage was 3.4 and then decreased to 1.5 after exposure for twenty-one months. Although the general air quality, as shown in Table 3, at Suburban is poorer than that in Pedder Bay, it is believed that the relatively high level of anthropogenic salt particles of submicron size is the primary cause of the high corrosion rate in the Victoria area. It is interesting to note that corrosion rate for mild steel at the coastal background site is very similar to that found at the interior background in Nelson.

TABLE 6
ATMOSPHERIC CORROSION OF MILD STEEL

Exposure Time Days	Suburban Motors (mill influenced)	Pedder Bay (coastal background)	Relative Corrosivity: Suburban Wt. Loss/ Pedder Bay Wt. Loss
	Av. Corrosion rate µm/yr	Av. Corrosion rate µm/yr	
133	36.5	20.6	3.4
275	34.5	19.5	2.6
427	31.5	18.5	1.7
559	30.5	16.0	1.9
628	27.5	15.0	1.6

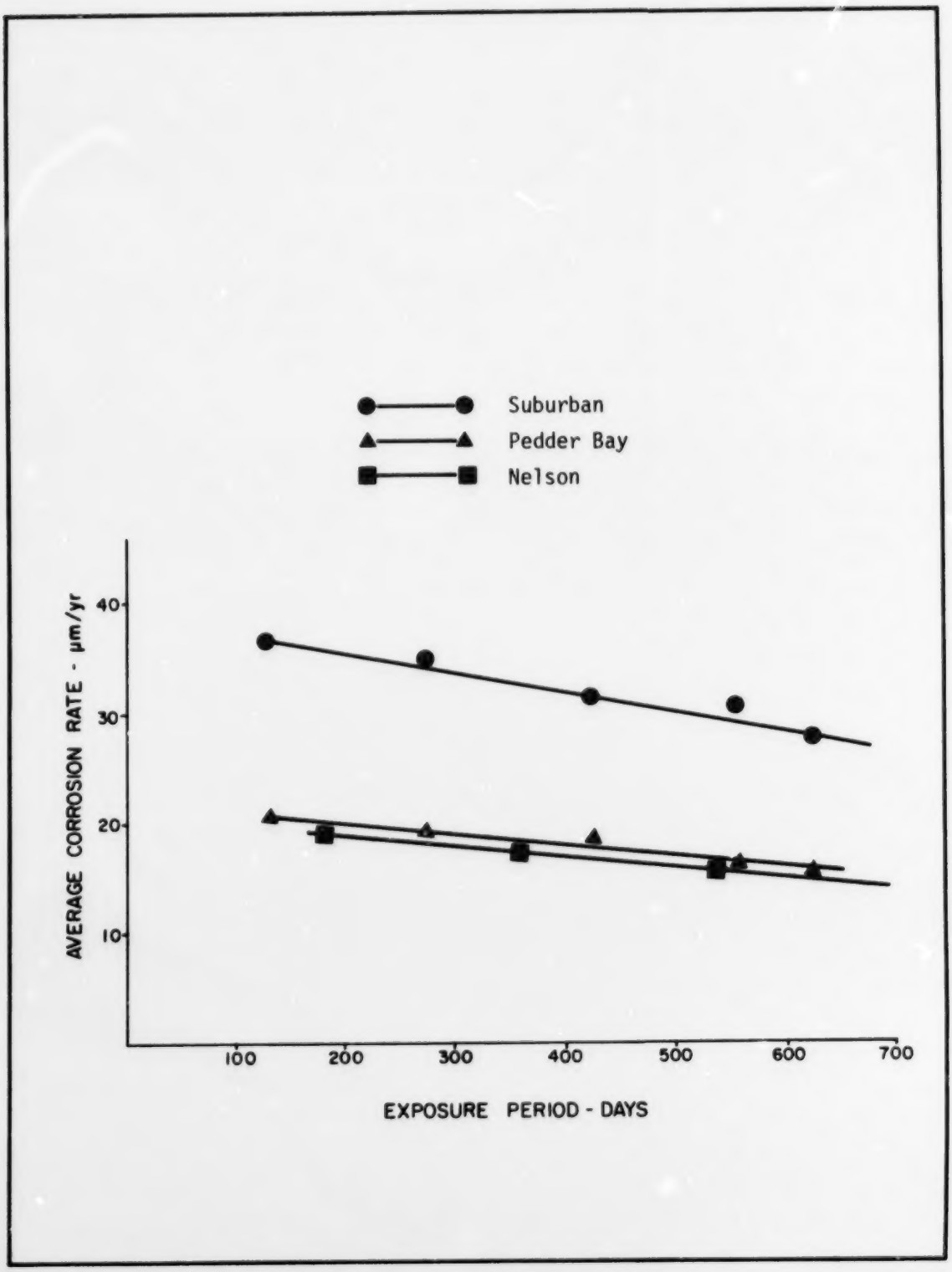

Figure 7 Average Corrosion Rate of Mild Steel in Victoria Area

CONCLUSION

Two separate corrosion studies, one near a pulp mill in the interior and the other near a woodwaste power boiler in coastal B.C., indicated that the corrosion impacts are significantly higher in the zone of influence than in the background areas. In the case of the pulp mill in the Castlegar area the corrosion loss is mostly due to the effects of the total reduced sulphur compounds, primarily hydrogen sulphide discharged from the Kraft operations. In the case of the woodwaste power boilers in Victoria, the increased corrosion impacts appear to be due to the high level of fine salt particles found in the ambient air in the downwind areas for the mill. In the absence of any relevant corrosion standards, it is a moot point whether relative corrosivity between the background and the zone of influence can be used as a measure of assimilative capacity of an area. Relative corrosivity may be used as an overall performance indicator of industrial operations in a certain area. Direct determination of assimilative capacity is extremely difficult since the system involves too many dynamic functions. Corrosion rate like any other ambient air parameters will only indicate to what extent assimilate deterioration has occurred.

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